Leaf to Landscape Scale Remote Sensing of Arctic Vegetation Structure and Function

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Background

Modeling the fluxes and pools of carbon, water and energy is an essential part of understanding and quantifying the impacts of global change on terrestrial ecosystems. Process models require detailed information on vegetation states and properties to properly simulate these fluxes and pools as well as to minimize model projection uncertainties. A major focus of our research is the use of leaf, near-surface (tram, UAS), airborne and satellite remote sensing data to enable the spatial and temporal mapping of key plant traits and canopy properties related to ecosystem structure and functioning in the Arctic. These spatially and temporally rich maps are then used to iteratively inform modeling activities across the Arctic within a *ModEx* framework.

Leaf to canopy scaling

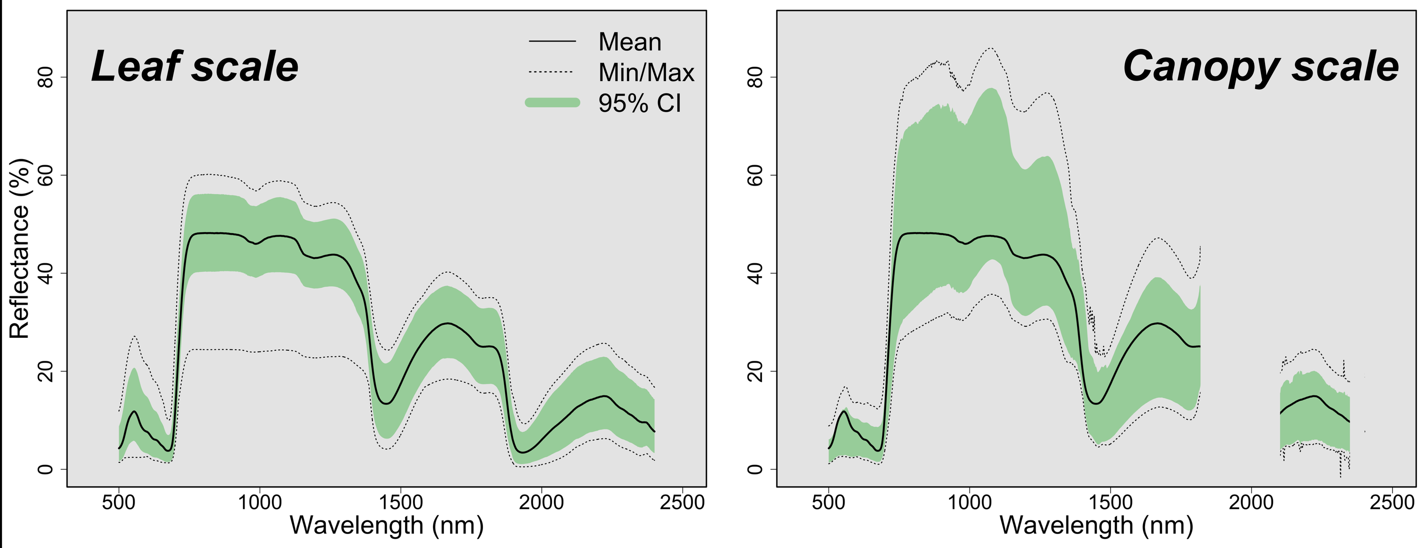

Figure 1. Leaf-level and canopy-scale reflectance measurements from a range of Arctic plant species found in Barrow and the Seward Peninsula, Alaska. Canopy measurements were made proximally, above a relatively homogenous monoculture in order to simplify the linkages between leaf traits and canopy spectra

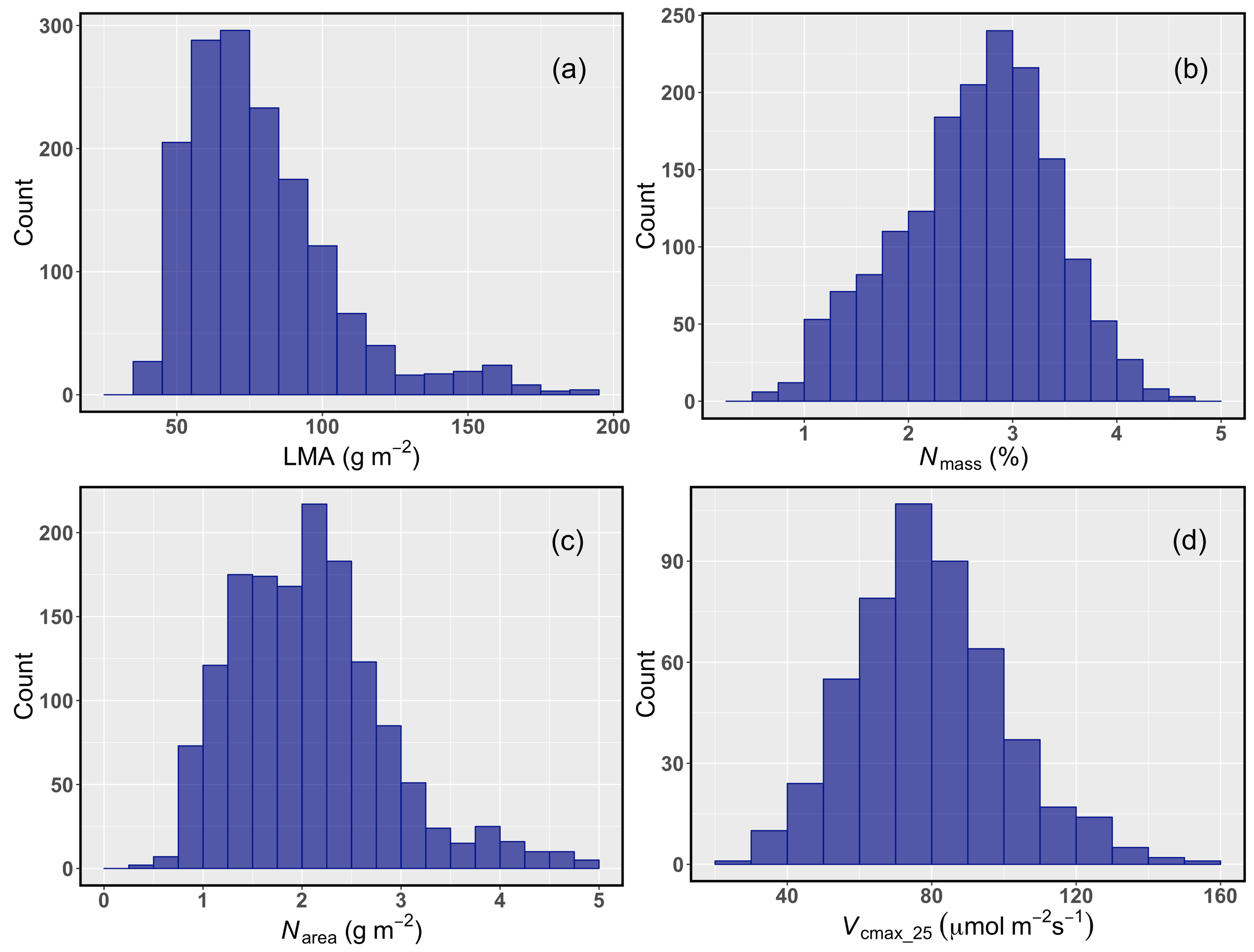

Figure 2. Trait histograms of leaf mass area (a), leaf foliar nitrogen concentration (b), foliar nitrogen content (c), and the leaf-level maximum rate of RuBisCo carboxylation (V_{cmax}, d). Using partial least-squares regression (PLSR) modeling we are linking spectral signatures at the leaf and canopy scales to these leaf traits to develop algorithms (Figure 3) to enable scaling

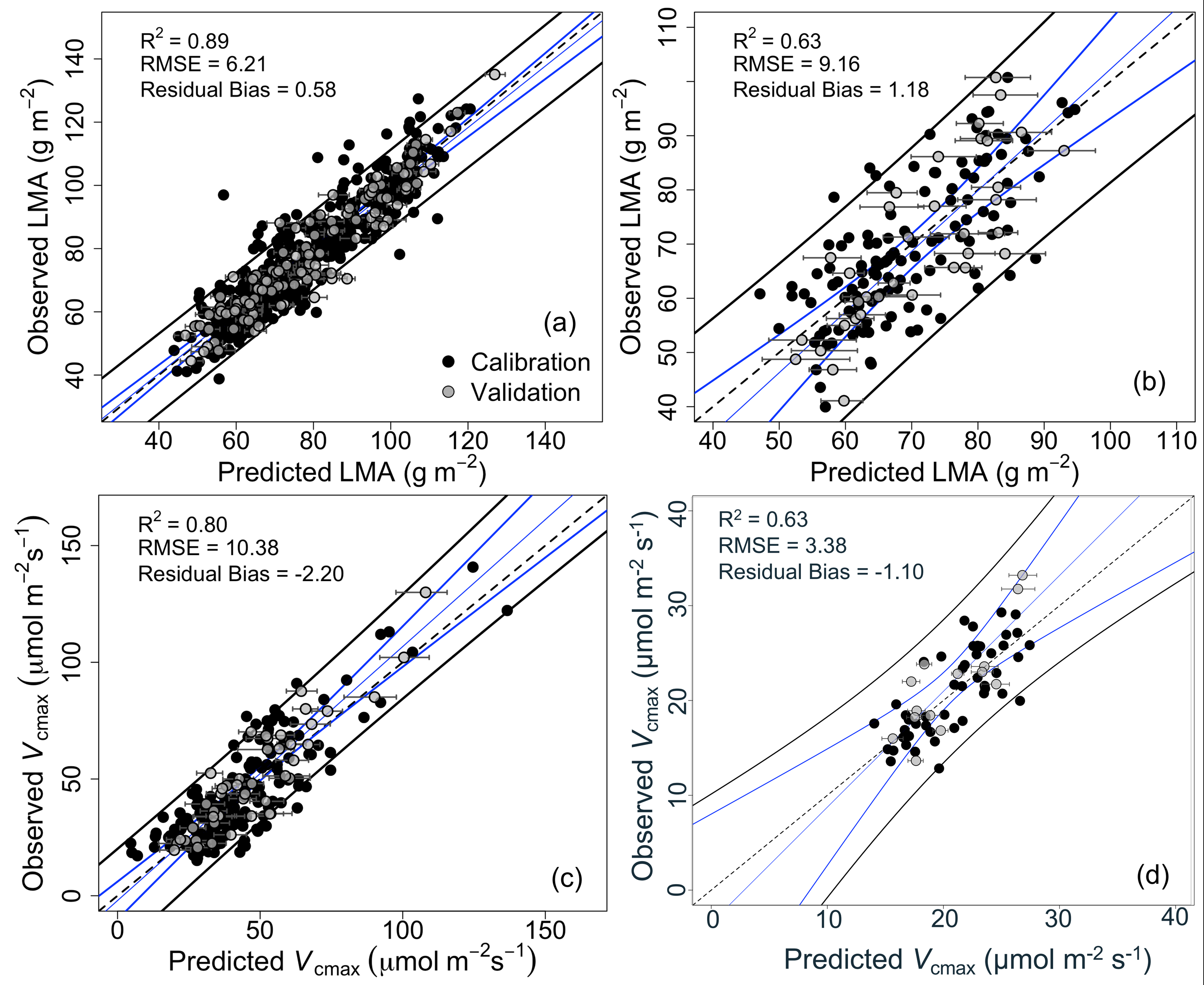

Figure 3. Example PLSR models using leaf (left) and canopy-scale (right) spectra. Our approach includes the characterization of prediction uncertainty shown here as the 95% confidence intervals around each predicted value. Validation statistics shown

Canopy to Landscape

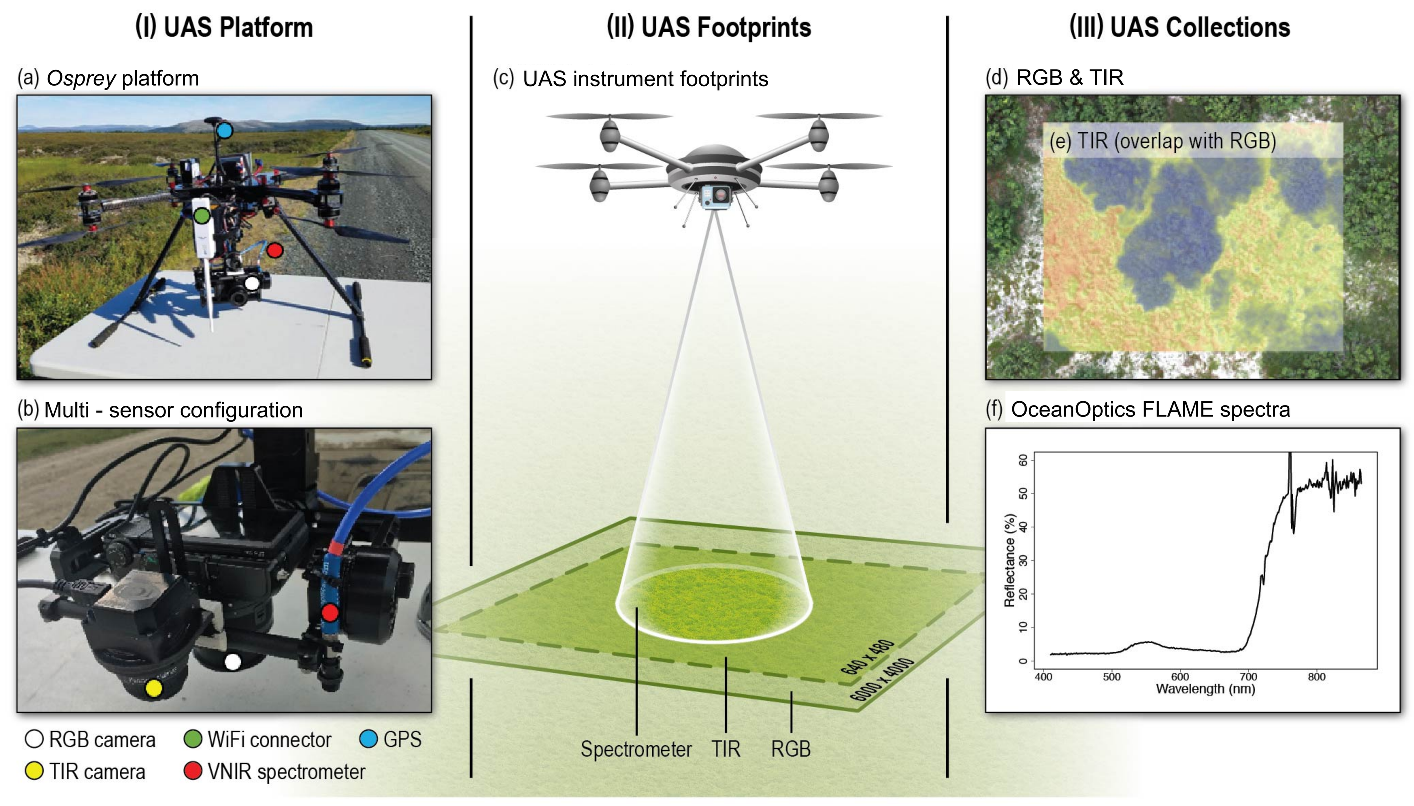

Figure 4. Our *Osprey* octocopter UAS (Meng et al., in prep) platform used to collect very high spatial and spectral resolution reflectance, canopy structure, and thermal infrared (TIR) properties of Arctic vegetation. The platform contains a high-resolution digital camera, dual spectrometers for downwelling irradiance and upwelling radiance measurements, and a thermal infrared camera. The onboard WiFi data link provides real-time instrument monitoring and control

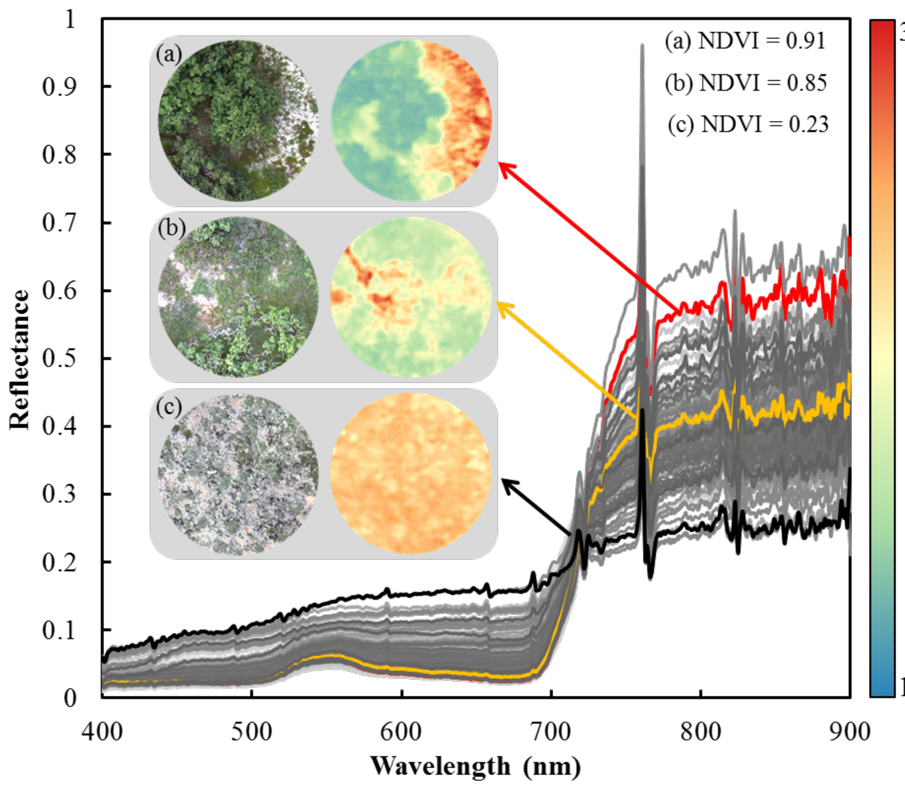

Figure 5. Example canopy reflectance spectra collected from the *Osprey* platform from the Kougarok example flight. The subplots are corresponding footprints of RGB and TIR measurements.

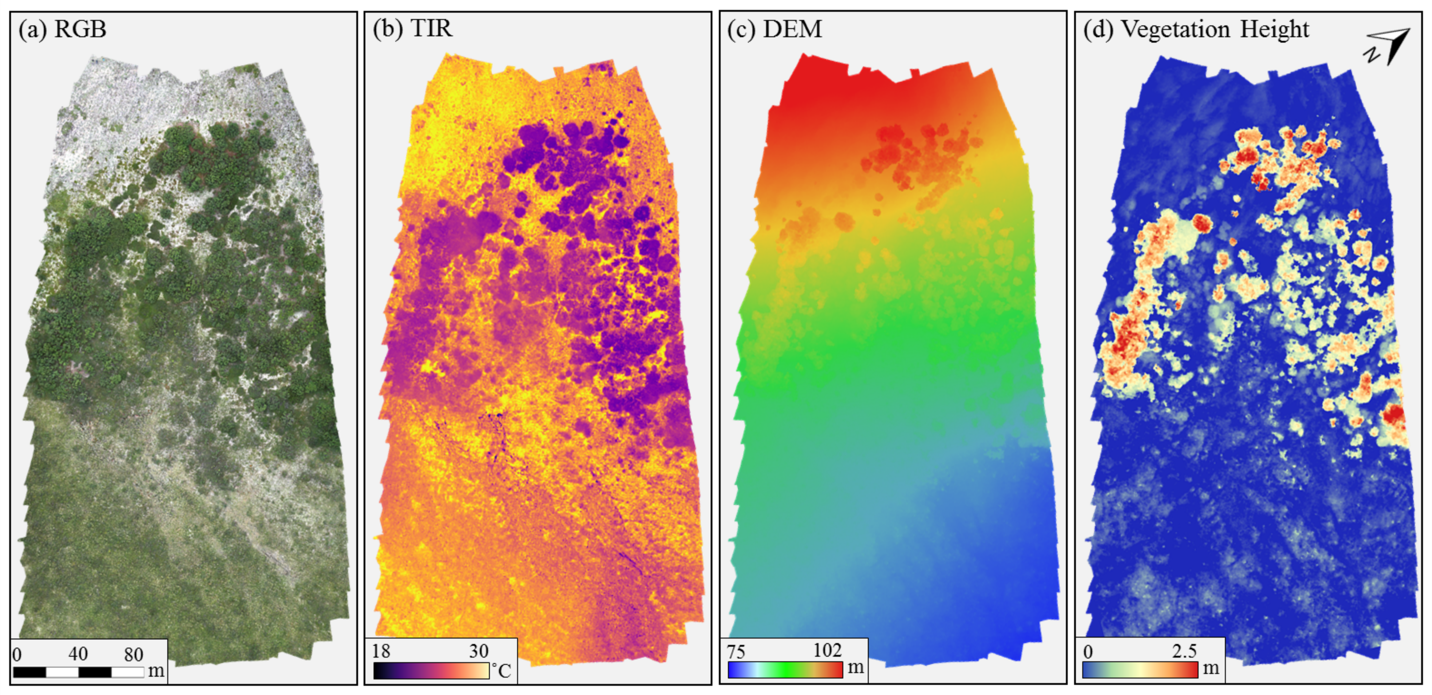

Figure 6. Osprey products from a UAS flight over the Kougarok site: optical RGB imagery (a), thermal-infrared (TIR) imagery (b), Digital Earth Model (DEM) (c), vegetation height (d), derived from optical imagery and structure-from-motion.

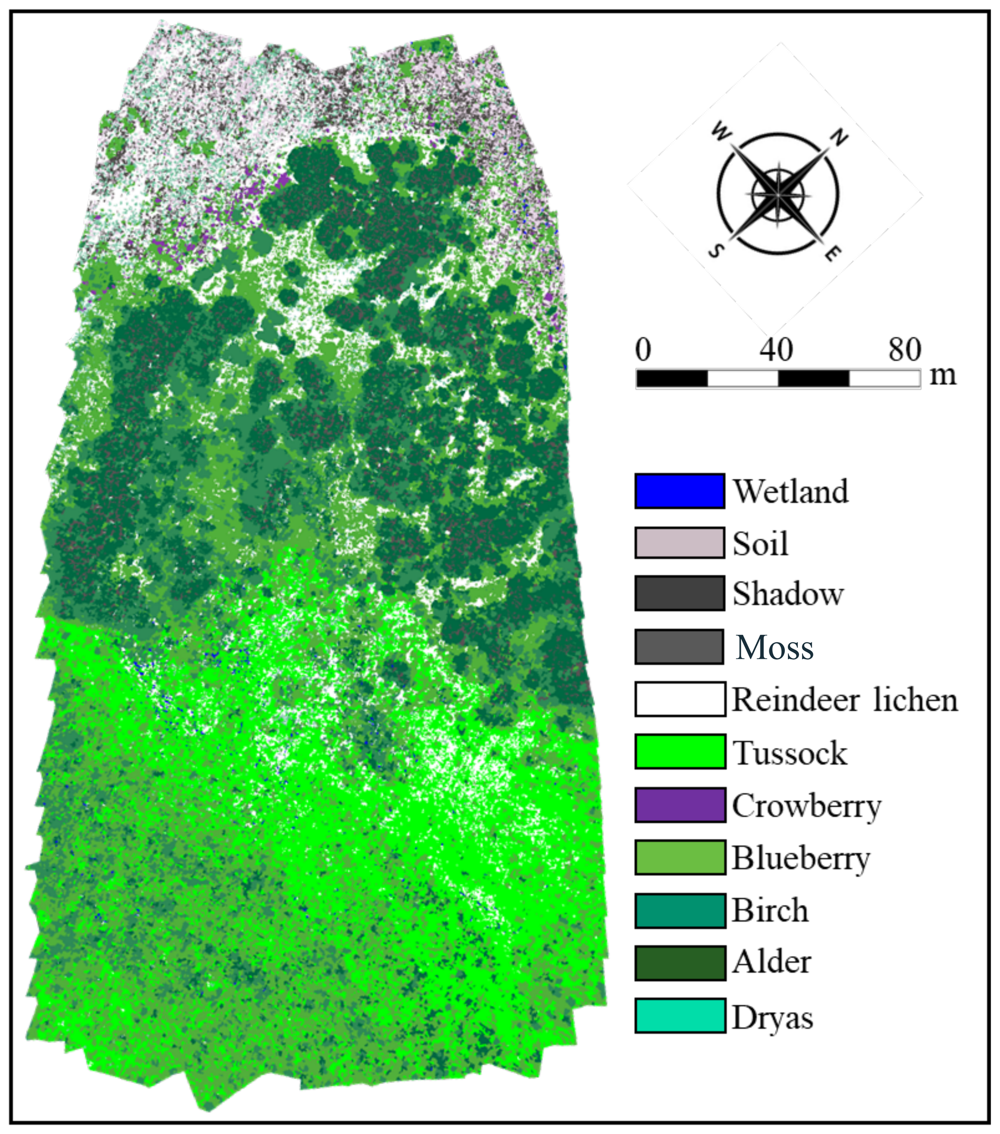

Figure 7. Preliminary vegetation classification map for the Kougarok site derived using the spatial, spectral, and structural information from our UAS collections and initial post-processing.

Landscape to Region

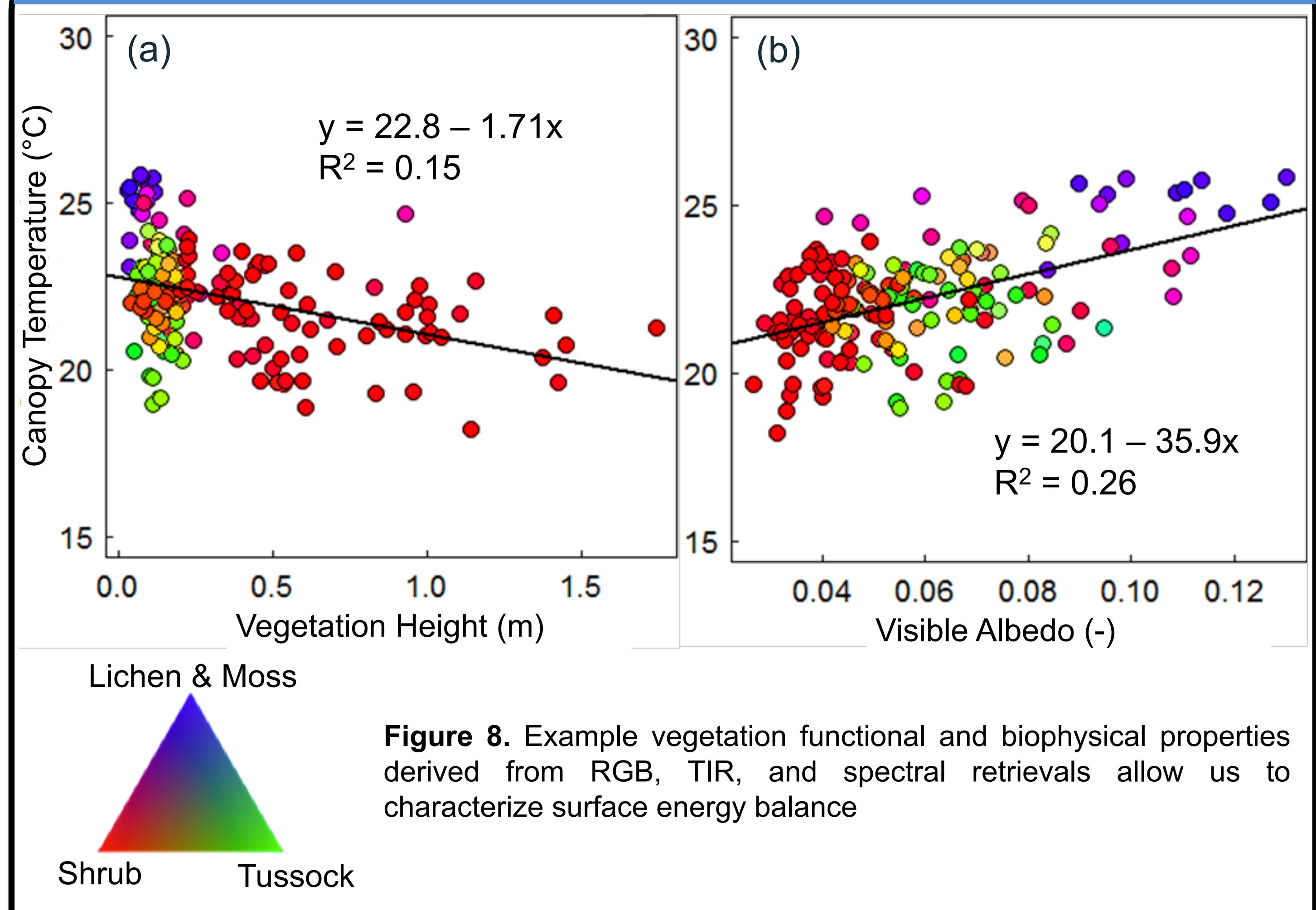

Figure 8. Example vegetation functional and biophysical properties derived from RGB, TIR, and spectral retrievals allow us to characterize surface energy balance

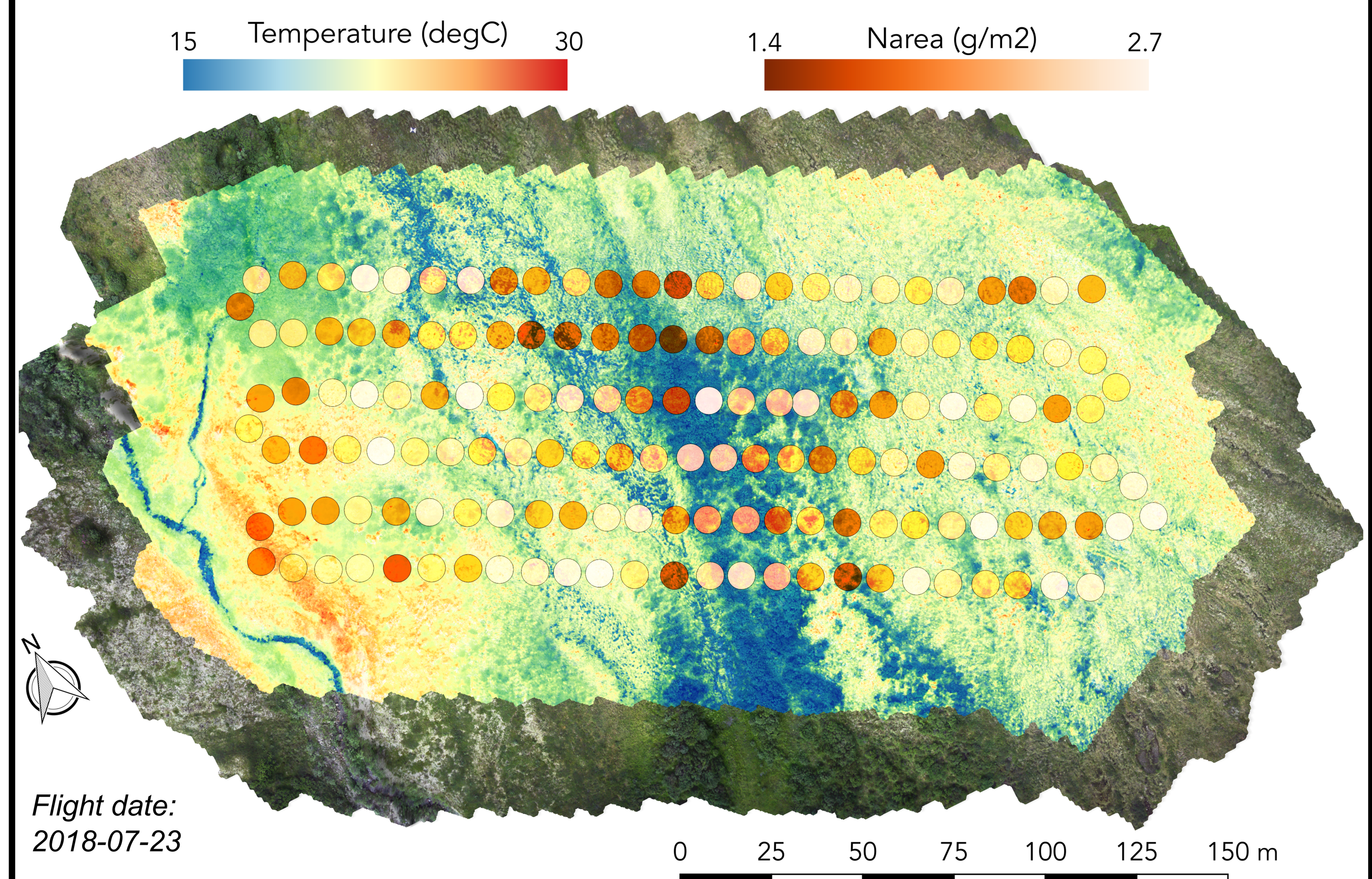

Figure 9. Map of spatial variation in surface temperature across shrub and tussock tundra at the Teller site overlaid on an RGB ortho-mosaic. Darker areas show lower temperatures (shrubs) while the redder areas are typically dominated by mosses and lichens. Spectroscopic estimates of leaf nitrogen content (circles) derived from measured surface reflectance data collected with our dual point spectrometer setup (Fig. 4) and our canopy spectra-trait PLSR model

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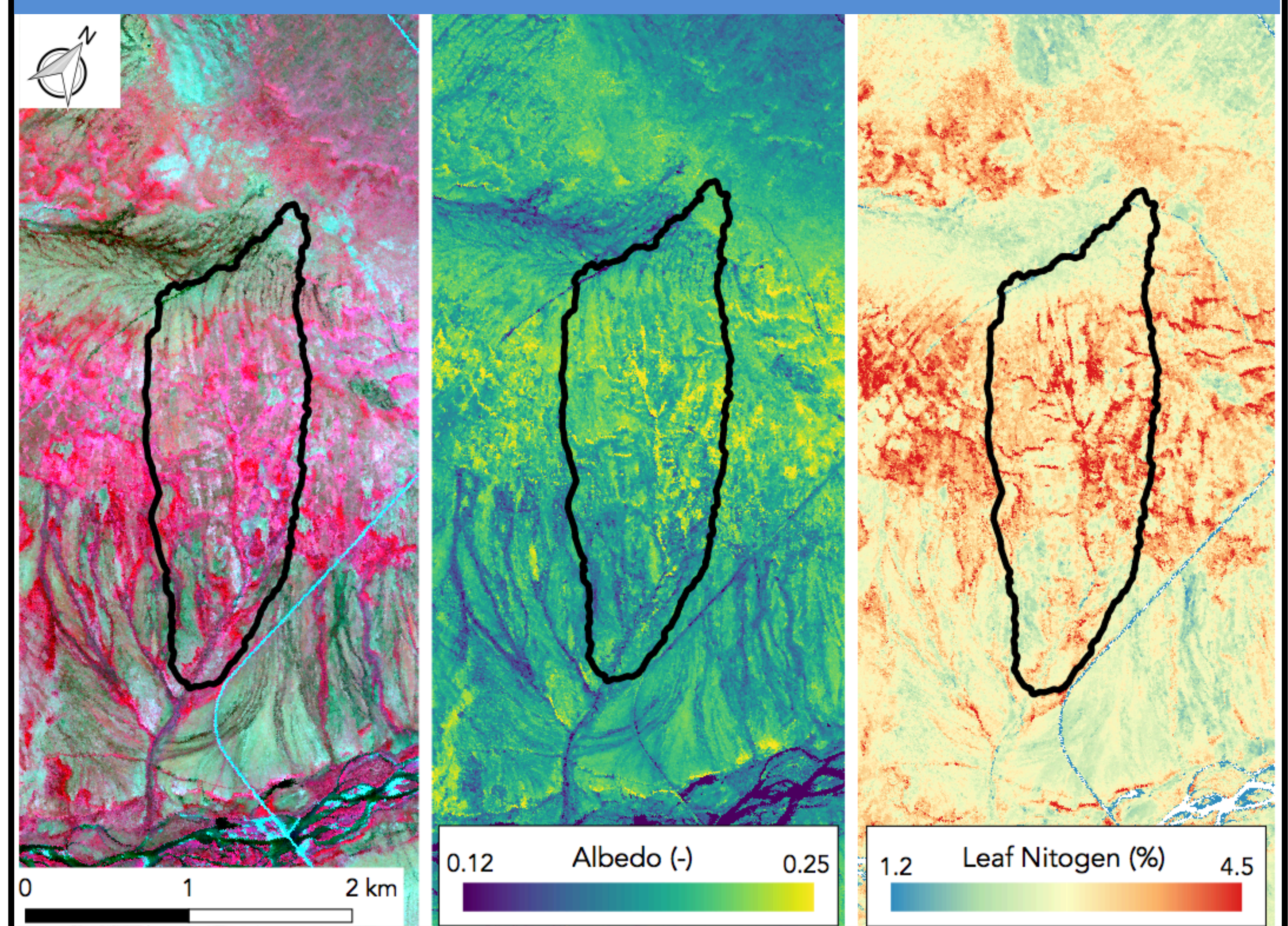

Figure 10. AVIRIS imagery over the Teller study site, where the left image shows a VNIR composite with deeper red colors representing sedges, dwarf and tall shrubs, while pale colors are less dense vegetation (e.g. tussock). The albedo map (center) highlights the wetter shrub water tracks which generally have lower albedo than the surrounding vegetation. A leaf nitrogen map is shown on the right.

Conclusions

- Our work illustrates the strong capacity to scale up leaf physiological traits using spectroscopy and thermal remote sensing
- We can map Arctic functional traits across scales, from leaf to region
- UAS imagery is an effective means to bridge scales and link key plant biophysical properties to ecosystem functioning